Indonesian Journal of Engineering and Technology (INAJET) Vol.8 No.2 April 2026
e-ISSN: 2623-2464 https://journal.unesa.ac.id/index.php/inajet

Milkfish Aquaculture System Selection in Supporting Food Security via System Dynamics Simulation

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Abstract

Food security related to animal protein is an important factor in supporting sustainable development, particularly through the aquaculture sector. This study aims to analyze the key factors affecting the profitability of milkfish aquaculture, develop a dynamic simulation model for milkfish production, and evaluate alternative development scenarios for traditional and intensive aquaculture systems. The research was conducted in Tambakberas Village, Cerme District, Gresik Regency, involving 60 milkfish farmers. Data were collected through observations, interviews, questionnaires, and secondary data on fish production and consumption. The analysis was carried out using Structural Equation Modeling–Partial Least Squares (SEM-PLS) and System Dynamics through causal loop diagrams and stock-and-flow diagrams. The results show that all examined variables have a positive and significant effect on profit. Milkfish production was identified as the most statistically significant factor, with an original sample value of 0.305, a T-statistic of 2.837, and a p-value of 0.005. The simulation results indicate that intensive aquaculture systems generate higher profits than traditional systems. Among the developed scenarios, Scenario 3, which increases stocking density and seed quantity while maintaining an 85% survival rate, provides the highest profit and production performance throughout the simulation period. Furthermore, supply chain activities play an important role in supporting stock availability, product distribution, and market stability, thereby contributing to the fulfillment of consumer demand for milkfish in East Java..

Keyword: *milkfish, aquaculture system, traditional system, intensive system, food security, dynamic simulation, supply chain.*

I. INTRODUCTION

Food security related to animal protein is a highly important indicator of sustainable national development. Demand for fishery products continues to increase in line with population growth and greater public awareness of nutritional needs (Rasman, Theresia, and Aginda, 2023). The aquaculture sector plays an important role in meeting this demand, especially through commodities with high economic value that can be cultivated widely in coastal areas. Gresik Regency is the main contributor to milkfish production in East Java, accounting for 63% of the province's total production. This commodity ranks as the leading regional commodity, with a total harvest volume of 90.504 Tons

Table 1 Milkfish commodity in Gresik Regency

Commodity	Production in Year (Tons)		
	2021	2022	2023
Milkfish	90398	90488	90504

(Source: (BPS, 2021, 2022, 2023))

Previous studies have widely applied the System Dynamics approach to analyze food commodity supply chains and availability. (Anaking dan Suryani, 2020) used System Dynamics to analyze the beef supply chain in order to improve product availability and supply chain value. (Sirajuddin, Bhaswara dan Gunawan, 2022) developed a dynamic model of the broiler chicken industry to predict meat supply and demand (Fadhillah, Nurhayati dan Fitrimawati, 2023) analyzed the availability of beef in West Sumatra through population and production dynamics modelling. Furthermore, (Murnawan dan Saves, 2025) developed a dynamic model to improve food security through increased broiler chicken availability in East Java. In the fisheries sector, (Laksmiati, Tama dan Hamdala, 2024) evaluated the value chain of milkfish aquaculture using a System Dynamics approach to formulate sustainability strategies. Their study identified ten key variables influencing milkfish farming performance and demonstrated that strategies such as organic fertilizer utilization, feed reduction, organic pest control, and increased stocking density could improve farmers' profitability and long-term sustainability. However, these studies mainly focused on livestock commodities and have not specifically addressed milkfish aquaculture supply chain performance from the perspective of production system comparison. In addition, previous studies generally employed System Dynamics as the primary analytical tool without integrating statistical analysis to identify the key factors affecting aquaculture performance. Therefore, a research gap exists regarding the integration of SEM-PLS and System Dynamics approaches in evaluating milkfish aquaculture systems and supply chain performance.

The novelty of this research lies in the integration of SEM-PLS and System Dynamics methods to identify the factors influencing aquaculture success, compare traditional and intensive milkfish farming systems, and simulate their impacts on production performance and supply chain fulfillment in East Java. The main issue identified in this study is the gap between the potential profitability of intensive aquaculture systems and the preferences of farmers, who still tend to maintain traditional systems. Farmers generally choose traditional aquaculture because it is perceived as safer, requires lower capital investment, and is easier to operate. However, in terms of production capacity and market value, the intensive system offers greater economic potential.

The System Dynamics approach provides a modelling framework that can represent the complexity of causal relationships and feedback mechanisms within a supply chain system in a simulative and quantitative manner. Through this approach, key variables such as seed costs, feed costs, fertilizer costs, selling prices, and production volume can be integrated into a comprehensive model. This enables the simulation of various policy scenarios to identify the most economically profitable configuration of aquaculture systems. This method has been widely applied in studies of agricultural and fisheries commodity supply chains and is considered suitable for implementation in the local context of Tambakberas Village.

The System Dynamics approach is considered appropriate for analyzing the complexity of relationships among variables in aquaculture systems and supply chains in an integrated manner. System Dynamics can describe the relationships among biological, economic, and environmental factors using causal diagrams and policy scenario simulations (Murnawan dan Purnomo, 2026). Based on the background described above, the research questions in this study are: (1) What are the main factors influencing the success of traditional and intensive milkfish aquaculture production systems in Tambakberas Village based on SEM-PLS analysis? (2) How are the aquaculture scenario model and milkfish production outcomes represented in traditional and intensive systems through dynamic simulation?.

II. THEORY

A. Milkfish Aquaculture

Milkfish (Chanos chanos) is a vital euryhaline finfish in Indonesian brackish-water and paddy-field ponds (tambak), serving as an affordable protein source and supporting rural livelihoods (Riany, Partelow dan Nagel, 2023). Morphologically, it features a slender silver body, small head, adipose eye membranes, and a deeply forked caudal fin Hatchery-produced or wild-caught fry migrate from coastal areas to nursery facilities before entering grow-out ponds (Alimorin, 2025).

The production cycle sequence involves pond drying, soil/pest treatment, liming, fertilization, stocking, maintenance, and harvesting. Successful cultivation requires collective pond-commons governance (water gates and canals) (Riany, Partelow dan Nagel, 2023) and precise environmental controls predominantly acid-sulfate neutralization, salinity adjustment, and dissolved oxygen maintenance (Tarunamulia *et al.*, 2024). Operational efficiency is driven by feed and seed costs, robust monitoring of water parameters (pH, temperature), and standard bio-security filtration at inlets to prevent vector entries (Azhari *et al.*, 2025; Hidayat dan Pratama, 2026).

B. Food Security

Food security comprises four pillars: availability (physical supply), access (economic and physical capacity), utilization (nutritional efficacy), and stability (resilience against market or climate shocks) (Mumah, Hong dan Chen, 2025). In Indonesia, structural challenges persist across all pillars due to import dependency, infrastructural gaps, logistical bottlenecks, and climate-induced supply chain disruptions (Amin *et al.*, 2021; AlNemer, 2023). Within this matrix, milkfish farming acts as a strategic vehicle for stabilizing regional food supplies and generating alternative aquaculture incomes, though stable farm-level input costs remain critical to prevent upstream systemic disruptions (Amin *et al.*, 2021; Riany, Partelow dan Nagel, 2023). Therefore, food security depends not only on production capacity but also on the system's ability to maintain supply stability, distribution, prices, the utilization of nutritious food, and preparedness for potential food crises in the future (Rasman, Theresia dan Aginda, 2023).

C. Structural Equation Modeling-Partial Least Square (SEM-PLS)

PLS-SEM is a variance-based multivariate approach designed to maximize the explained variance of endogenous constructs and identify key structural drivers (Hair *et al.*, 2022). It is highly suited for exploratory research, complex higher-order models, and field studies with small-to-medium sample sizes where strict data normality assumptions cannot be met (Sarstedt, Ringle dan Hair, 2021; Cepeda *et al.*, 2024)Outer Model Evaluation: Assesses reliability and validity via indicator outer loadings (>0.70), Average Variance Extracte 0.50 for convergent validity, the Heterotrait-Monotrait ratio < 0.85–0.90 for discriminant validity, and Composite Reliability 0.70–0.95 (Hair, 2019; Hair *et al.*, 2022). Inner Model Evaluation: Assesses structural paths using the coefficient of determination R^2, path coefficients pm 1, bootstrapping derived t-statistics/p-values for significance testing, and predictive relevance Q^2 (Hair *et al.*, 2022).

D. Dynamic Simulation

System Dynamics tracks temporal feedback loops, delays, and non-linear interactions within complex systems, mapping variables like seed quantity, feed logistics, costs, and market availability (Rahmawati dan Murnawan, 2025). Modeled through Stock-and-Flow Diagrams (SFD), the accumulation in a stock over a time step dt is calculated as, these changes can be expressed using the following formula:

$$\text{Stock}(t) = \text{Stock}(t - dt) + (\text{Inflow} - \text{Outflow}) \times dt \quad (1)$$

The amount of inventory at a given time is influenced by the previous inventory, plus the difference between inflow and outflow. In addition, to ensure that the simulation results correspond to the actual data, model validation can be conducted using the following formulas:

Mean Comparison

$$E1 = \frac{|\bar{S} - \bar{A}|}{\bar{A}} \quad (2)$$

Description:
$\bar{S}$ = Mean value of the simulation results
$\bar{A}$ = Mean value of the data
The model is considered valid when E1 ≤ 5%.

Error Variance

$$E2 = \frac{Ss - Sa}{Sa} \quad (3)$$

Description:
Ss = Standard deviation of the simulation results
Sa = Standard deviation of the data
The model is considered valid when E2 ≤ 30%.

Hybrid modeling framework combines the static, empirical validation of PLS-SEM with the longitudinal, feedback-driven projection capability of System Dynamics. In this approach, statistically significant path coefficients derived from the SEM-PLS inner model serve as the mathematical foundation and parameter inputs for the SFD converter equations (Richter dan Tudoran, 2024). This structural linkage eliminates arbitrary model parameterization, allowing validated interactions between aquaculture variables and food security indicators to drive dynamic scenario simulations (Richter dan Tudoran, 2024).

III. METHOD

This research was conducted in Tambakberas Village, Cerme District, Gresik Regency, with a focus on both traditional and intensive milkfish aquaculture systems. Primary data were obtained through direct field observations, interviews with pond farmers, and questionnaires used to measure the factors influencing aquaculture success. Secondary data were obtained from information on milkfish production in Gresik Regency, fish consumption data in East Java, and supporting literature on aquaculture, supply chains, and system dynamics.

The study involved 60 milkfish farmers as respondents. Respondents were selected using a purposive sampling technique, targeting farmers who were actively engaged in milkfish aquaculture activities in Tambakberas Village and had sufficient experience in pond management. The characteristics of respondents were identified based on several aspects, including age, education level, farming experience, pond area, and aquaculture system applied. These characteristics were used to provide a better understanding of the factors influencing milkfish production and profitability.

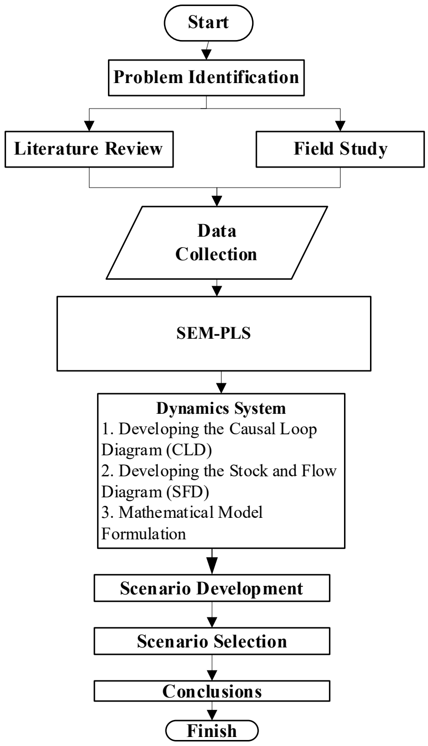

Figure 1 Research Flowchart
(Source : Saidha, 2026)

The data processing workflow commenced with problem identification, followed by an extensive literature review, field investigations, and data collection. The questionnaire instruments were quantitatively analyzed using Structural Equation Modeling Partial Least Squares (SEM-PLS) to evaluate validity, reliability, and to test the hypothesized effects of operational convenience, productivity, milkfish production, and human resources on profit. Indicators were deemed valid if the outer loading values exceeded 0.70 and the Average Variance Extracted values exceeded 0.50. Furthermore, statistical significance for the hypothesized relationships was established at a p-value less than 0.05.

Table 2 Operational Definition and Measurement of Variables

No	Variable Name	Variable Type	Measurement Scale
1	Productivity	Independent Variable	Likert Scale (1-5)
2	Milkfish Production	Independent Variable	Likert Scale (1-5)
3	Selection of milkfish aquaculture	Independent Variable	Likert Scale (1-5)
4	Human Resources	Independent Variable	Likert Scale (1-5)
5	Profit	Dependent Variable	Likert Scale (1-5)

(Source : Saidha, 2026)

The dominant factors identified through the SEM-PLS analysis were subsequently utilized as the empirical foundation for developing the system dynamics model. The conceptual framework of this model was initially constructed using a Causal Loop Diagram to illustrate the feedback loops and cause and effect relationships. This qualitative model was then translated into a quantitative Stock and Flow Diagram to simulate dynamic changes in land area, productivity, production, revenue, expenditure, and overall profit.

Table 3 Parameters Utilized in the System Dynamics Model

No	Parameter	Unit	Description
1	Land Area	Hectare (Ha)	Total area of milkfish ponds used for cultivation.
2	Productivity	Kg/Ha	Milkfish production generated per hectare of pond area.
3	Business Balance	Indonesian Rupiah	Available capital used for farming operations.
4	Milkfish Production	Ton	Total milkfish harvest produced in one culture cycle.
5	Survival Rate	%	Percentage of fish that survive until harvest.
6	Seed Quantity	Rean	Number of milkfish fry stocked at the beginning of cultivation.
7	Fish Weight	Gram/Fish	Average weight of milkfish at harvest.
8	Selling Price	IDR/kg	Market price received for milkfish sales.
9	Operational Cost	Indonesian Rupiah	Total expenditure incurred during cultivation.
10	Profit	Indonesian Rupiah	Difference between revenue and operational cost.

(Source : Saidha, 2026)

The completed system dynamics model was then simulated over a multiyear time horizon to project the future trends of milkfish production, financial performance, and overall aquaculture sustainability. The output of these simulations serves as an analytical foundation to formulate strategic recommendations for maximizing profits and ensuring the longterm sustainability of milkfish farming in Gresik Regency.

IV. RESULTS AND DISCUSSION

1. SEM-PLS

Examine the factors influencing profit in milkfish aquaculture, a Structural Equation Modeling Partial Least Squares (SEM-PLS) approach was employed. The proposed model consists of four independent variables, namely Productivity, Milkfish Production, Selection of Milkfish Aquaculture, and People, which are hypothesized to affect Profit as the dependent variable. The SEM-PLS model used in this study is presented :

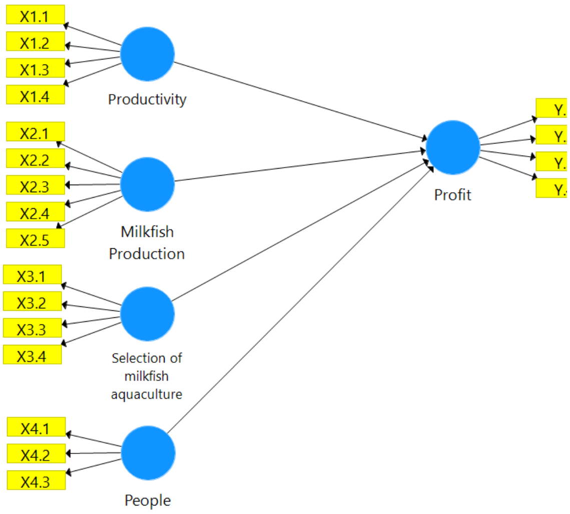

Figure 2 SEM-PLS Models
(Source : Saidha, 2026)

Illustrates the structural relationships between the independent variables and profit. Each latent variable is represented by several indicators measured using a five point Likert scale. The model was developed to identify the most influential factors affecting the profitability of milkfish aquaculture in Tambakberas Village. Before evaluating the relationships among variables, validity and reliability tests were conducted to ensure that all constructs adequately represented the variables under study. The results of the validity and reliability tests are presented in :

Table 4 testing its validity and reliability

Indicator	CA	Rho_A	CR	AVE
Selection of milkfish aquaculture	**0,857**	**0,867**	**0,903**	**0,699**
Profit	**0,825**	**0,834**	**0,884**	**0,656**
Milkfish Production	**0,848**	**0,87**	**0,888**	**0,614**
Productivity	**0,925**	**1,001**	**0,945**	**0,811**
People	**0,779**	**0,855**	**0,866**	**0,683**

(Source : Saidha, 2026)

All variables achieved Cronbach's Alpha and Composite Reliability values greater than 0.70, indicating satisfactory reliability. Furthermore, all Average Variance Extracted (AVE) values exceeded 0.50, confirming convergent validity. These results demonstrate that all indicators are valid and reliable and can therefore be used for further structural analysis. After confirming the adequacy of the measurement model, hypothesis testing was conducted using the bootstrapping procedure. The results are presented in

Table 5 Testing Bootstraping

Indicator	*Original Sample*	*Sample Mean*	*STDev*	*TStat*	*PValues*
Productivity -> Profit	0,285	0,288	0,104	2,312	**0,032**
Selection of milkfish aquaculture -> Profit	0,319	0,326	0,115	2,783	**0,006**
Milkfish Production-> Profit	0,305	0,323	0,108	2,837	**0,005**
People-> Profit	0,273	0,266	0,137	1,992	**0,047**

(Source : Saidha, 2026)

The bootstrapping results indicate that all independent variables have a positive and significant effect on profit, as evidenced by p-values below 0.05. Milkfish Production was identified as the most statistically significant variable affecting profit, with an Original Sample value of 0.305, a T-statistic of 2.837, and a p-value of 0.005. This was followed by Selection of Milkfish Aquaculture with an Original Sample = 0.319, T-statistic value of 2.783, p-value value of 0.006, Productivity with an Original Sample value of 0.285, T-statistic value of 2.312, p-value value of 0.032, and People with an Original Sample value of 0.273, T-statistic value of 1.992, p-value value of 0.047. These findings indicate that improvements in milkfish production, cultivation system selection, productivity, and human resource capacity contribute to increasing the profitability of milkfish farming. The significant variables identified through the SEM-PLS analysis were subsequently used as the basis for developing the system dynamics model.
To analyze the dynamic interactions among production, economic, and operational factors, a system dynamics approach was employed. The first stage of model development involved constructing a causal loop diagram to illustrate the causal relationships among variables. The causal loop diagram was then transformed into a stock and flow diagram to simulate the behavior of the milkfish aquaculture system over time.

2. Causal loop diagram

The following causal loop diagram shows the relationships among variables in the milkfish aquaculture system.

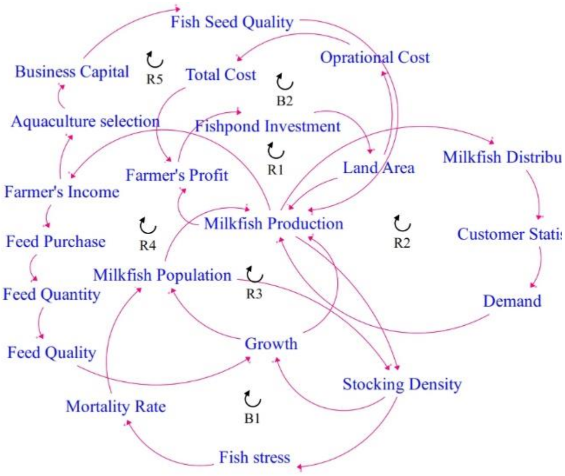

Figure 3 Milkfish causal loop diagram
(Source : Saidha, 2026)

The dynamic simulation model for milkfish aquaculture shows complex interactions between economic and biological factors through several mutually influential causal loops. Increased investment in ponds (R1) and smoother market distribution (R2) consistently encourage production growth and increase profits for pond farmers. Production success is strongly influenced by stocking-density management (R3) and the availability of quality feed (R4) to support optimal fish growth. Nevertheless, the system has natural control limits caused by biological factors, namely stress levels and fish mortality resulting from excessive population density. From an economic perspective, system balance is maintained because business-scale expansion automatically raises operational costs, which limits profit. The overall value-accumulation dynamics in this model are analyzed in greater depth through stock components covering land area, productivity, and financial balance.

3. Stock and flow diagram

The following stock-and-flow diagram (SFD) illustrates the flows and changes of variables in the milkfish aquaculture system.

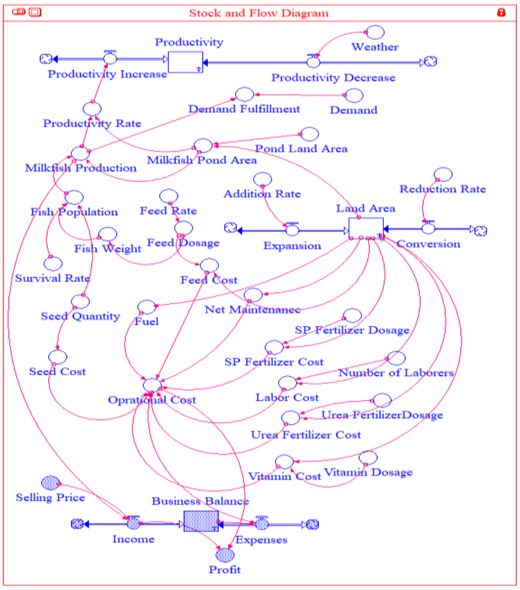

Figure 4 Milkfish Stockand Flow Diagram
(Source : Saidha, 2026)

Finally, the financial aspect was analyzed through estimated business income and expenditure, whose trends are presented in the figure. Based on the simulation data, milkfish farmers' income tends to increase each year. Although operational cost components rise due to inflation in feed and fertilizer inputs, their total remains far lower than the accumulated business income. These simulation results indicate that the economic activities in the developed milkfish

4. Scenario

Based on the simulation results, the scenarios applied in this study consist of:

1. Base Model: Traditional milkfish aquaculture condition
2. Scenario 1 : Full implementation of intensive aquaculture
3. Scenario 2: Survival Rate on 85%
4. Scenario 3 : Higher Stocking Density and fish seed

Based on the simulation configuration, the specific parameters applied to each evaluated scenario are structured.

Table 6 Parameter Customization Across Simulation Scenarios

Parameter	Base Model	Scenario1	Scenario2	Scenario3
Harvest frequency per year	3 cycles	3 cycles	3 cycles	3 cycles
Number of fry (nener)	3 rean	3 rean	3 rean	6 rean
Fry conversion	16,500 fish	16,500 fish	16,500 fish	33,000 fish
Survival rate	50%	50%	85%	85%

Parameter	Base Model	Scenario1	Scenario2	Scenario3
Feed	2,5 sacks	130 sacks	130 sacks	130 sacks

(Source : Saidha, 2026)

Based on the multi-year simulation results from 2026 to 2030, the financial performance of milkfish ponds exhibits distinct variations under each structural intervention. The comparative analysis of profit trajectories is explained as follows:

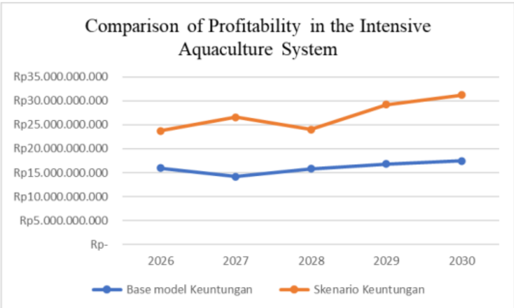

Figure 8 Comparison of Profitability in the Intensive Aquaculture System
(Source : Saidha, 2026)

In Scenario 1, the full implementation of the intensive system yields a consistently higher profit trajectory than the traditional baseline model from 2026 to 2030. Under Scenario 1, profits initiate at approximately IDR 23.6 billion in 2026 and dynamically expand to IDR 31.2 billion by 2030, despite a temporary structural drop to IDR 24.0 billion in 2028. Conversely, the base model reflects a lower growth path, shifting marginally from IDR 15.9 billion to IDR 17.5 billion. This proves that shifting into intensive inputs significantly enhances economic productivity.

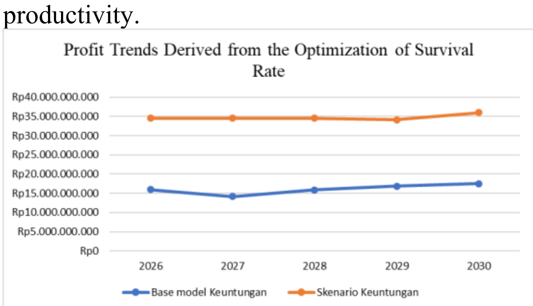

Figure 9 Profit Profit Trends Derived from the Optimization of Survival Rate
(Source : Saidha, 2026)

In Scenario 2, maximizing the biological survival rate to 85% generates a highly stable and elevated income stream. The profit under Scenario 2 is sustained within a high, robust band between IDR 34.5 billion and IDR 36.1 billion throughout the five-year horizon. This substantial divergence from the base model demonstrates that mitigating risk and optimizing survival yields superior economic resilience and returns compared to mere intensive system shifting with high mortality rates.

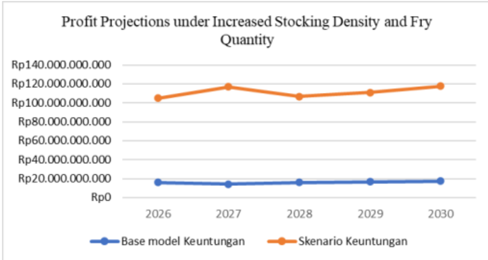

Figure 10 Profit Projections under Increased Stocking Density and Fry Quantity
(Source : Saidha, 2026)

In Scenario 3 doubling the stocking density to 6 rean (33,000 fish) while maintaining an 85% survival rate drives an exponential leap in absolute profits. The financial return directly surges to a range between IDR 105.1 billion and IDR 118.2 billion. The massive volume of biomass harvested successfully offsets the expanded feed expenditures, making it the most superior scenario in terms of absolute net generation.

In summary, the simulation results demonstrate that intensive structural adjustments significantly outpace traditional models. While Scenario 3 offers the absolute maximum financial yields, it incurs severe capital risks due to high input scaling. Scenario 2 provides an exceptional mid-tier alternative, delivering robust stability with balanced operational expenditure risks. Therefore, the recommended development framework for local farmers is to adopt a combined policy: transitioning systematically toward Scenario 2 to lock in an 85% survival rate, followed by a gradual increase in stocking density Scenario 3 backed by strict feed management efficiency.

V. CONCLUSIONS.

Based on the results of the study on traditional and intensive milkfish aquaculture systems, it can be concluded that the dominant factor influencing the success of the production process, based on the SEM-PLS analysis, is the milkfish production factor, with a path coefficient of 0.305, a T-statistic of 2.837, and a p-value of 0.005. Furthermore, the system dynamics simulation demonstrates that all development scenarios generate higher profits than the traditional aquaculture model. Among the evaluated scenarios, Scenario 3, which combines higher stocking density and fish seed quantity with an 85% survival rate, produces the highest profitability throughout the simulation period. This scenario is capable of significantly increasing production output and business income despite requiring higher operational inputs. In addition, supply chain activities play an important role in meeting consumer demand for milkfish in East Java through smooth distribution, adequate stock availability, and market price stability.

Based on these findings, local farmers are advised to gradually implement intensive aquaculture practices and improve feed efficiency so that production costs remain manageable. Local governments are also expected to provide training, capital assistance, and support for high-quality feed to accelerate pond modernization. Future studies may further incorporate additional variables such as market prices, extreme weather conditions, fish diseases, and model testing in other aquaculture areas.

REFERENCE

Alimorin, J.M.L. (2025) "Sustainable Aquaculture Practices for Milkfish (Chanos chanos): An Integrated Analysis of Environmental, Economic, and Policy Dimensions in Asia," International Journal of Research and Review, 12(7), hal. 468–490. Tersedia pada: https://doi.org/10.52403/ijrr.20250749.

AlNemer, H.A. (2023) "The COVID-19 pandemic and global food security: a bibliometric analysis and future research direction," International Journal of Social Economics, 50(5), hal. 709–724.

Amin, F. et al. (2021) "Determinants of post COVID-19 food security policy success," International Journal of Disaster Resilience in the Built Environment, 13(4), hal. 440–450. Tersedia pada: https://doi.org/10.1108/IJDRBE-11-2020-0118.

Anaking, P. dan Suryani, E. (2020) "Beef Supply Chain Analysis to Improve Availability and Supply Chain Value Using System Dynamics Methodology," IPTEK Journal of Proceedings, 6, hal. 229–234.

Azhari, D. et al. (2025) "Agribusiness Performance of Milkfish and Vannamei Shrimp in a Polyculture System," International Journal of Economic, Finance and Business Statistics (IJEFBS), 3(4), hal. 231–248.

BPS (2021) Produksi dan Nilai Produksi Perikanan Budidaya Menurut Provinsi dan Komoditas Utama, 2021, 2023. Tersedia pada: https://www.bps.go.id/id/statistics-table/3/TkdGeFN5OUJVVmxVTjBSclZrbFROalUzVW5KQmR6MDkjMw==/volume-produksi-dan-nilai-produksi-perikanan-budidaya-menurut-provinsi-dan-komoditas-utama1--2018.html?year=2021.

BPS (2022) Produksi dan Nilai Produksi Perikanan Budidaya Menurut Provinsi dan Komoditas Utama, 2022, 2024. Tersedia pada: https://www.bps.go.id/id/statistics-table/3/TkdGeFN5OUJVVmxVTjBSclZrbFROalUzVW5KQmR6MDkjMw==/volume-produksi-dan-nilai-produksi-perikanan-budidaya-menurut-provinsi-dan-komoditas-utama1--2018.html?year=2022.

BPS (2023) Statistik Perikanan dan Peternakan Kabupaten Gresik. Tersedia pada: https://gresikkab.bps.go.id/id/statistics-table/2/MTc4IzI=/gresik3525.github.io.

Cepeda, G. et al. (2024) "Emerging Opportunities for Information System Researchers to expand their PLS-SEM analytical toolbox," Industrial Management & Data System, 1(1), hal. 11–27.

Fadhillah, D., Nurhayati dan Fitrimawati (2023) "Analysis of Beef Availability in West Sumatra Using the Dynamic System Model," Wahana Peternakan, 7(3), hal. 337–352.

Hair, J.F. (2019) "When to use and how to report the results of PLS-SEM," 31(1), hal. 2–24. Tersedia pada: https://doi.org/10.1108/EBR-11-2018-0203.

Hair, J.F. et al. (2022) An Introduction To Structural Equation Modeling. Sage Pulication, Inc.

Hidayat, Y.T. dan Pratama, M.I. satria (2026) "Techniques and Management Practices in the Polyculture of Pacific White Shrimp (Litopenaeus vannamei) and Milkfish (Chanos chanos)," Journal of Sustainable Supply Chain and Technology, 1(1), hal. 111–119.

Laksmiati, N.N.D., Tama, ishardita P. dan Hamdala, I. (2024) "Evaluasi Rantai Nilai Dalam Strategi Keberlanjutan Budidaya Ikan Bandeng Dengan Simulasi Sistem Dinamis," Jurnal rekayasa sistem dan manajemen, 01(08), hal. 835–846.

Mumah, E., Hong, Y. dan Chen, Y. (2025) "Exploring the reality of global food insecurity and policy gaps," Humanities & Social Sciences Comunications, 1(2025), hal. 4–23.

Murnawan, H. dan Purnomo, H. (2026) "Optimization of Sustainable Dairy Production Processes: A System Dynamics Approach," Process Integration and Optimization for Sustainability [Preprint]. Tersedia pada: https://doi.org/10.1007/s41660-026-00732-x.

Murnawan, H. dan Saves, F. (2025) "Improving

Food Security in East Java Province Through Dynamic Modeling of Broiler Chicken Availability," Eastern-European Journal of Enterprise Technologies, 6(13), hal. 16–22. Tersedia pada: https://doi.org/10.15587/1729-4061.2025.338751.

Rahmawati, A.D. dan Murnawan, H. (2025) "System Dynamics Simulation of Semi-Organic Fertilizer and Pest Management Scenarios to Enhance Sustainable Food Security in Bungur Village," 8(1), hal. 25–32.

Rasman, A., Theresia, E.S. dan Aginda, M.F. (2023) "Analisis implementasi program food estate sebagai solusi ketahanan pangan Indonesia," Holistic: Journal of Tropical Agriculture Sciences, 1(1). Tersedia pada: https://doi.org/10.61511/hjtas.v1i1.2023.183.

Riany, C.F., Partelow, S. dan Nagel, B. (2023) "Governance challenges for Indonesian pond aquaculture : a case study of milk fi sh production in Gresik," Frontiers in Aquaculture, (September), hal. 1–16. Tersedia pada: https://doi.org/10.3389/faquc.2023.1254593.

Richter, F.N. dan Tudoran, A.A. (2024) "Elevating theoretical insight and predictive accuracy in business research : Combining PLS-SEM and selected machine learning algorithms," Journal of Business Research, 173(December 2023), hal. 114–453. Tersedia pada: https://doi.org/10.1016/j.jbusres.2023.114453.

Sarstedt, M., Ringle, C.M. dan Hair, J.F. (2021) Partial Least Squares Structural Equation Modeling. Springer Nature Switzerland.

Sirajuddin, Bhaswara, G. dan Gunawan, A. (2022) "Model sistem dinamis industri ayam pedaging dalam memenuhi kebutuhan daging ayam," journal industrial sevicess, 8(1), hal. 53–58.

Tarunamulia et al. (2024) "Impact of soil and water quality on the sustainable management of mangrove-compatible brackishwater aquaculture practices in Indonesia Impact of soil and water quality on the sustainable management of mangrove-compatible brackishwater aquaculture practice," Environmental Research Comunications, 6(1), hal. 1–19.